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EXPERIMENTAL DATA FORMING THE BASIS FOR

THE BOMBING TABLES BT-1000-B-1 FOR

THE BOMB, A.P., 1000-LB., M52

by

E. S. Martin

E. W. Crump

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STINFO BRANCH

EEL, APG, ED. 2100

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U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER BALLISTIC RESEARCH LABORATORIES ABERDEEN PROVING GROUND, MARYLAND

Ballistic Research Laboratory Report No. 253

ESM/EWC/ess Aberdeen Proving Ground, Md. April 10, 1942.

EXPERIMENTAL DATA FORMING THE BASIS FOR THE BOMBING TABLES

BT-1000-B-1

FOR THE

BOMB, A.P., 1000-LB., M52

#### Abstract

This report records the essential data on which the bombing tables, BT-1000-B-1, are based. A short description of the bomb is given as well as the mechanical constants of the bombs used. The methods used in range bombing and the methods of obtaining essential data are described. Also given are the methods used to determine the ballistic coefficients, as well as the methods used in constructing the bombing tables. Graphs showing the results of range bombing and graphs showing the fitted C: Y relations are included.

#### I. Purpose of Report

The purpose of this report is to record the essential details of the experimental work, the computing methods and the experimental data upon which the bombing tables, BT-1000-B-1, for the Bomb, A.P., 1000-lb., M52 are based. PROPERTY OF U.S.

#### II. <u>Description of Bombs</u>

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The Bombs, A.P., 1000-1b., M52 used in range bombing for the bombing tables, BT-1000-B-1, were made in accordance with Picatinny Arsenal Drawing Number 26454, dated February 6, 1941. The present Ordnance Drawing Number is:82-0-58, dated September 15, 1941.

This armor-piercing bomb was made by converting the 12<sup>th</sup> Deck Piercing Shell, M1898 (Ordnance Drawing Number 75-12-4D). The shells have been converted into bombs by adding lugs to the body and by adding a fin assembly to the tail of the shell. The base plug has been altered so that the fuze hole is smaller and a smaller adapter is used. The rotating bands have been machined so that they have the same diameter as the bomb body. One half of the bombs dropped in this range bombing program were modified and half were unmodified. The unmodified bombs were equipped with

### PHYSICAL CHARACTERISTICS

# BOMB, A.P., 1000-LB., M52 DRG. NO. 82-0-58 REV. 9-15-41

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lug-bands and were filled with Explosive D. The modified bombs had their lugs screwed on the body and were filled with cast TNT. The unmodified bombs are numbered 12, 14, 16, 18, 20, 22, 24, 26, and 28. The modified bombs are numbered 11, 13, 15, 17, 19, 21, 23, 25 and 27. The modified bombs carried an experimental designation of T1.

The bomb is assembled with Fuze, Bomb, Tail, MlO2 (modified). This is a vane type fuze with a 0.04 to 0.06 second delay. The bomb was equipped with steel box-type fins. The percentage of bursting-charge to actual weight as dropped is 5.4 per cent. The range bombing program was authorized in correspondence 00 471.62/222.

#### III Preparation of Bombs

The bombs were fully loaded when received at the Proving Ground, so that it was only necessary to assemble fins and fuzes to them.

#### IV Mechanical Constants of Bombs

The mechanical constants of each bomb were determined before it was loaded into the airplane. The detailed results of these measurements are given in Appendix A. A summary of the results for the Bomb, A.P., 1000-lb., M52 is given in the table below:

	m Weight Complete as Dropped	of Gravity from Nose	Inertia about Transverse Axis through Center of Gravity
Mean Standard Deviation Maximum Minimum  MNumber of Bombs	1b. 1080.3 2.30 1086.0 1076.5	in.  28.32 0.15 28.82 28.13	1b.ft. <sup>2</sup> 1566 7 1584 1552

No moments of inertia about the longitudinal axis were obtained for these bombs.

These statistics refer to all bombs for which a ballistic coefficient with respect to any element was obtained. The actual variations in weight of these bombs do not affect their flight characteristics sufficiently to cause a variation in ballistic coefficient large enough to be detected by the methods for estimating the ballistic coefficient which were used in the reduction of field data. The variation in center of gravity position and moments of inertia would, if sufficiently in excess of that for the present bombs, affect the yaw of the bombs and thereby the dispersion in the elements range, time of flight and trail.

The positions of the centers of gravity of the bombs summarized above were measured with fins and fuzes.

#### V. <u>Description of the Range Bombing</u>

The bombs in this range bombing program were dropped from the B-18A. and the B-23 airplanes at a target anchored in Bush River in Such a position that the release points were in the fields of view of the Vertical and Oblique Cameras Obscura. The direction of the approach to the release points on all runs was from southeast to northwest within 15°

On all approaches on which bombs were dropped horizontal flight was maintained as nearly as possible. In all cases except May 3, 1941, the piloting was done by means of the automatic flight control equipment. On this date the equipment did not work and the piloting was done manually.

In these airplanes the bomb racks are so arranged that the longitudinal axis of the bomb is nearly parallel to the thrust line of the airplane. Hence the initial yaw of the bomb in the vertical plane is nearly equal to the angle of attack of the airplane.

On all approaches with the B-18A airplane, the bombs were carried in the rear bank of the bomb racks. The center line of this rack is 12.8 feet to the rear of the point formed by the junction of the front edge of the wing with the fuselage of the airplane, this junction being the point on the airplane plotted in the cameras obscura. The corresponding distance in the B-23 is 12.1 feet.

All bombs were dropped according to the current standard practice of the Air Corps, using the current standard bomb sight and a target in Bush River as an aiming point. The results of this range bombing are shown in Appendix B. For the

The effect of bomb bay release position on the estimated values of the ballistic coefficients is discussed in Ballistic Research Laboratory Report No. 136: "First Progress Report: On the Method of Reduction of Observations on the Elements of Bomb Trajectories."

purpose of this report, the displacement of the center of impact with respect to the target is of no special significance. The dispersion about the center of impact and other data summarized in Appendix B are, however, of considerable interest.

The bombs dropped were divided into groups and the endeavor was made to have the altitude and air speed within the group approximate as nearly as possible to certain specified values. These values were described as the standard altitude and the standard air speed.

The number of bombs in each group and the standard altitude and standard air speed for each group are given in Appendix D. The reasons for the selection of these standard altitudes and air speeds are given in Sections VI and IX of this report.

The range bombing was conducted by the following:

#### Pilots:

Capt. S. C. Smink, A.C. First Lt. R. Billings, A.C. First Lt. A.C Perry, A.C. First Lt. C.A. Reissaus, A.C.

#### Bombardiers:

Capt. M. F. Summerfelt, A.C. Capt. S. C. Smink, A.C.

#### Proof Officers:

Capt. J. G. Shinkle, O.D. Mr. C. Brown, O.D.

#### VI. Ground Observations

The primary ground observational equipment employed was the Camera Obscura Installation. The position of the aircraft in space and its components of velocity were fundamental data obtained by reduction of observations made with this equipment.

Compare the usage of these terms for statistical purposes in Sections VIII and IX of this report.

A basic description of the Camera Obscura Installation is given in the "First, Second and Third Progress Reports on Bomb Trajectory Study by the Camera Obscura Method" by Frank Short, F. V. Ludden and S. P. Willan. The equipment has been extensively modified and improved during 1938 and the current equipment and its accuracy are described in Ballistic Research Laboratory Report No. 144: "First Progress Report: On the accuracy of the Camera Obscura Installation for Obtaining the Initial Data of Bomb Ballistics."

The field data for determinations of times of flight were secured by the chronograph installation housed in the Vertical Camera Obscura. The instants of release and impact were recorded by this chronograph-hydrophone system which has been in use in the present form since 1937. In addition the field data for determinations of the times of flight of 8 bombs were obtained by the Western Electric Camera Clock. The clock in the camera is started by the same radio release signal that is recorded by the chronograph-hydrophone system cited above. The camera photographs the impact of the bomb on Bush River and the clock face within the camera at the same instant. The rate of the camera at this time was approximately 200 frames per second.

The coordinates of the impacts referred to the camera coordinate system were obtained by the ground observers by means of azimuth instruments on three towers along the shore of Bush River and were furnished to the Bombing Unit of the Ballistic Research Laboratory. The ground observers also provided the dispersion data with reference to the target and the reduced meteorological data for securing corrections to the elements tabulated in the bombardier's approximate bombing tables. The latter results are graphically summarized in Appendix B, "Primary Results of Range Bombing".

The field data necessary for the reduction of the effects of non-standard meteorological conditions were obtained from two sources. The data secured by the camera observers were the coordinates on the camera plotting boards of smoke puffs at regular time intervals for a series of altitudes, to be used in obtaining ballistic winds; the velocity and the direction of the wind at the earth's surface; and the temperature, the relative humidity and the barometric pressure of the air at the earth's surface. The data secured by the Range Observation Section observers were the spatial positions of a balloon at regular time intervals, and the velocity and direction of the wind at the earth's surface. The temperature and barometric pressure at a series of altitudes were obtained from the bombing flight records of the bombardier. These data were partially reduced by the Range Observation Section and were furnished to the Bombing Unit in the form of tables of:

The calibration of this system and the measurement of the systematic errors to which it is subject were carried out in 1938 and are described in Ballistic Research Laboratory Report No. 130: "On the Measurement of the Time of Flight of Bombs". The absolute accuracy and internal precision of the method in actual practice has been determined recently and the results are given in Ballistic Research Laboratory Report No. 211: "Comparison of Measures of the Time of Flight of Bombs by the Camera Obscura Chronograph and the Western Electric Clock".

- (1) The actual wind components at a series of altitudes, and
- (2) The density of the air at a series of altitudes relative to standard ordnance air density structure.

The actual wind components were taken along a fixed line of known azimuth in the bombing lane, with the sign positive when taken along the direction of flight and positive when taken to the right. The actual wind components and the densities were obtained as near to the time the bombs were dropped as was practicable.

Field data on range bombing with the Bomb, A.P. 1000-1b., M52 for the bombing tables, BT-1000-B-1, were obtained from the program carried out between April 28, 1941 and June 6, 1941. This included range bombing at 2,000, 10,000 and 25,000 foot altitudes. The advance of ballistic theory and increased accuracy of measurement during 1938 and 1939 showed that better results can be obtained from groupings at the maximum obtainable altitude of release, a central altitude and a low altitude.

Field data for both range and time of flight were obtained and trail determinations were made wherever possible. A total of 17 ranges, 21 times of flight and 19 trails was obtained.

#### VII. Reduction of Field Data

The data secured by the ground observers at the cameras were utilized to obtain the position and velocity of the airplane at the instant of release. The data secured by the ground observers at the azimuth instruments were utilized to obtain the positions of impact of the bombs. The time intervals obtained from the chronograph strip were employed to determine the uncorrected interval between release and impact. The time intervals from the Western Electric Camera film were likewise utilized. These data were then corrected for instrumental errors.<sup>2</sup>

On May 27, 1941, Run Number 1, Bomb Number 23, the short range and less than vacuum times (microphone and Western Electric) indicate the bomb left the plane approximately 1/3 second before the release signal was received. Therefore the values were not included in the group mean.

The character of these instrumental errors is discussed in Ballistic Research Laboratory Reports No. 144, 130 and 211, previously cited.

#### VIII. Determination of Ballistic Coefficient

The reduction of field data furnished values of range and time of flight corresponding to a certain set of known values of altitude and air speed, but containing the effects of departures from standard ballistic table conditions. The method of reduction of field data in order to obtain ballistic coefficients with respect to range, time of flight and trail is discussed very briefly in Ballistic Research Laboratory Report No. 191. The computation of the ballistic coefficients is carried out by means of a Bomb Ballistic Reduction Table which was prepared in the Ballistic Research Laboratory.

In accordance with the principles remarked above the ballistic coefficients corresponding to the ranges, times of flight and trails were then deduced for each individual bomb. From these coefficients the ranges, times of flight and trails were then computed for the standard altitude and standard air speed of the group to which the bomb belonged. These are called the "standard ranges", the "standard times of flight" and the "standard trails", or in general, the "standard elements" and are given in Appendix C together with the corresponding ballistic coefficients. This appendix also lists the program, the group, the serial number stamped on the bomb, the date of release and the run number, the last two providing for comparison with Appendices A and B.

The standard elements and the ballistic coefficients corresponding thereto contain the effects of certain unknown instrumental inaccuracies and of certain departures from standard bombing table conditions which it was not feasible to remove in advance. However, the effects of these sources of dispersion were partially removed by the process used for construction of the bombing tables.

- Standard ballistic table conditions and standard bombing table conditions are discussed and compared in Ballistic Research Laboratory Report No. 145: "On the Theory of Motion of the Bomb".
- The method of reduction of field data in order to obtain ballistic coefficients with respect to range, time of flight and trail has undergone considerable evolution. The reports from which the present methods were developed include: Ballistic Research Laboratory File E-IV-3, "Explanations and Comparisons of the Camera Obscura Methods of Computation"; "Computation of Firing Tables for the U. S. Army"; and Ballistic Research Laboratory Report No. 136, previously cited.
- <sup>3</sup> A discussion of the ballistic coefficients corresponding to range, time of fkight and trail is given in Ballistic Research Laboratory Report No. 143: "Errors in Trail Resulting from Ignoring Either the Measured Range or the Measured Time of Flight".

#### IX. Construction of Tables

The experimental data from which the ballistic coefficients with respect to range, time of flight and trail were determined fell into 3 altitude groups. The groups were for standard altitudes of 2,000, 10,000 and 25,000 feet. The dependence of the ballistic coefficients upon altitude of release was determined from these 3 groups.

The mean standard elements for a standard true air speed and altitude were determined for each altitude group. The mean standard element is the arithmetic mean of the individual standard elements.1 The individual standard elements used in computing the mean standard elements had been reduced to the group standard altitude and true air speed. The use of the mean standard elements reduces the influence of the accidental errors in the individual standard elements upon the elements tabulated in the bombing table. The ballistic coefficients corresponding to these mean standard elements were then deduced. The forms of the functional dependence upon altitude of the three ballistic coefficients have been derived theoretically and verified empirically. The lift is the cause mainly responsible for the character of the variation of the ballistic The lift is due to the yaw arising coefficients with altitude. from the initial angular velocity of the tangent to the trajectory. The effects of lift are allowed to remain in the ballistic coefficients corresponding to the mean standard elements. The functional relations referred to are:

When time of flight was obtained by both the chronograph-hydrophone system and the Western Electric Camera Clock for one bomb, the average resulting is given a weight of 2 in the determination of the airthmetic mean. The average trail resulting from one measure of range and an average of the two times of flight was given a weight of 1.5.

The derivation of the form of these relations between the ballistic coefficients and the altitudes of release is discussed in Ballistic Research Laboratory Report No. 145, previously cited.

$$c_{X_{y}} = \frac{c_{X_{\infty}}}{1 + \sqrt{\frac{k_{X}C_{X_{\infty}}}{Y}}}$$

$$c_{T_{y}} = \frac{c_{T_{\infty}}}{1 + \sqrt{\frac{k_{T}C_{T_{\infty}}}{Y}}}$$

$$c_{\lambda_{y}} = \frac{c_{\lambda_{\infty}}}{1 + \sqrt{\frac{k_{X}C_{\lambda_{\infty}}}{Y}}}$$

These curves each contain two empirical qualtities k and  $C_{\infty}$ . The subscript  $\infty$  refers to the mean effective ballistic coefficient for infinite altitude, and k is a parameter determining the shape of the curve.

A new procedure for estimating the values of  $C_{X_{\infty}}$ ,  $C_{T_{\infty}}$ ,

 $c_{\lambda_m}$ ,  $k_{\chi}$ ,  $k_{\eta}$  and  $k_{\lambda}$  was in use when these bombing tables were computed. The first modification consisted in changing the method of weighting the points. The earlier procedure assigned weights proportional to the product of the number of bombs in the group and a factor dependent upon a priori considerations of the probable accuracy of the determination. No account was taken of the fact that the probable error of bombing is an increasing function of the altitude of release. In consequence, unduly great weight was attached to the groups of bombs at the high altitude. new procedure for range and trail used weights proportional to the product of the number of bombs in the group, a factor dependent upon a priori considerations of the probable accuracy of the determination and the reciprocal of altitude of release. The new procedure for the time of flight used weights proportional to the product of the number of bombs in the group, a factor dependent upon a priori considerations of the probable accuracy of the determination, the reciprocal of the altitude and the standard true air speed. The second modification consisted in a change of the functions to be minimized. The function minimized in the earlier procedure was the sum of the weighted squares of the residuals of the reciprocal ballistic coefficients. The finction minimized in the new procedure was the sum of the

weighted squares of the residual differences between the mean standard elements and those elements which would result from the use of the bombing tables. This modification has resulted in much smaller probable ballistic errors for bombing tables. A considerable improvement in the accuracy of the bombing tables, has resulted therefrom. The improvement is shown by the magnitude, as compared with earlier bombing tables, of the differences between the observed mean standard ranges, times of flight and trails, and those elements which would result from employment of these tables.

The values  $C_{X_\infty}$ ,  $C_{T_\infty}$ ,  $C_{\lambda_\infty}$ ,  $k_X$  and  $k_\lambda$  were deduced by the new procedure described above;  $k_T$  was shown to be without significance in the present instance. The values were:

$$C_{X_{\infty}} = 5.155$$
;  $C_{T_{\infty}} = 4.282$ ;  $C_{\lambda_{\infty}} = 3.722$   
 $k_{X} = -1.832$ ;  $k_{T} = 0$ ;  $k_{\lambda} = -7.848$ 

The observed and fitted ballistic coefficients are compared in Tables 1, 2 and 3 of Appendix D. The relations between the fitted ballistic coefficients and the altitudes of release are shown in Plots I, II and III of Appendix D. The fitting provides for obtaining the ballistic coefficient for any altitude of release. The actual points on the plots in Appendix D are shown by dots and their probable errors by horizontal strokes placed on the sides of the dots. The computed C: Y relations are shown by heavy lines. The dotted lines furnish the probable error of forecast bands. The band is determined by addition and subtraction of the probable error of the computed C: Y relation from the curve.

The construction of the Table of DS followed general instructions given in file 00 063.2/4524 (Confidential). The trail angles, times of flight and dropping angles were obtained by interpolation with the fitted C: Y relations in the Bomb Ballistic Auxiliary Tables, computed in the Ballistic Research Laboratory. These tables give trail angles, times of flight and dropping angles as functions of the altitude of release, Y; the calibrated indicated air speed, V, or true ground speed,

 $V_g$ ; and the reciprocal ballistic coefficient,  $\frac{1}{C}$ . The intervals

The new procedure is described more completely in Ballistic Research Laboratory Report No. 136, previously cited.

The ballistic error is a term originally used by British ballisticians to denote the difference between the bombing table range and the mean standard range for the same conditions. The ballistic error is denoted by X-X<sub>f</sub> in this report.

of the arguments used in the Bomb Ballistic Auxiliary Tables are the same as those used in the present series of abridged bombing tables. The small differences between the observed mean standard ranges, times of flight and trails, and those elements which would result from employment of these tables are shown in the columns X-X<sub>f</sub>, T-T<sub>f</sub> and  $\lambda - \lambda_f$  given in Tables 1, 2 and 3 of Appendix D. These differences are compared with the probable errors of the observed mean standard elements in Plots IV, V and VI of Appendix D. The importance of employment of the fitted C<sub>X</sub>: Y, C<sub>T</sub>: Y and C<sub>\lambda</sub>: Y curves is shown by Y Y

The range of arguments included in these bombing tables, BT-1000-B-1, is indicated in the table below:

Element	Spe mi.,	eed /hr.	Altitude ft.			
	Mini- mum	Maxi- mum	Mini- mum	Maxi- mum		
Trail Angle (Calibrated Indicated Air Speed)	100	250	1800	35000		
DS (Calibrated Indicated Air Speed)	1	60	1200	36000		
Time of Flight (Calibrated Indicated Air Speed)	1	60 1	1000	35000		
Dropping Angle (Ground Speed)	100	250	100	10000		

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E. W. Crump

Appendix A

Mechanical Constants of Bombs

Appendix A

Mechanical Constants of Bombs<sup>1</sup>

Program Group Serial Number	Date of Release Run Number	m Weight Complete as Dropped	Distance of Center of Gravity from Nose	I <sub>T</sub> Moment of Inertia about Transverse Axis through Center of Gravity
-11 -12 -15 -14 -13 -16 -17 -18 -19 -20 -21 -22 -23 -24 -25 -26 -27	4/28/41-1 2 4/29/41-1 2 3 5/3/41-1 2 5/26/41-1 2 5/27/41-1 6/3/411 1 2 6/6/411	1b.  1080.5 1082.5 1080.0 1080.0 1077.5 1079.5 1079.5 1086.0 1078.5 1081.0 1077.5 1080.5 1084.0 1079.5 1082.0 1080.0	in.  28.35 28.21 28.31 28.27 28.45 28.22 28.82 28.82 28.31 28.32 28.13 28.44 28.32 28.21 28.27 28.27 28.27 28.27 28.44	15.ft. <sup>2</sup> 1566 1579 1565 1561 1568 1562 1570 1571 1559 1552 1572 1572 1572 1564 1558 1584 1566 1565

The moments of inertia about the longitudinal axis were not obtained for these bombs because there is no nose fuze hole for the adapter. Interference of the fins plus the fact of the bombs being H.E. loaded made suspension from the tail impractical.

Appendix B

Primary Results of Range Bombing

APRIL 28, 1941 1000 LB A P. BOMB TI

AIRPLANE 8-23

з ома	TIME	ALTI	TUDE GR'ND	<del> </del>	R SPE			CLIMB OR GLIDE		DEVIA	······		TARGET
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# RESULTS OF RANGE BOMBING NO. 149 APRIL 29, 1941 1000 LB A.P. BOMB TI AIRP

AIRPLANE 8-23

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RESULTS OF RANGE BOMBING NO. 152 1000 LB A.P. BOMB TI MAY 3,1941 AIRPLANE 8-23 PILOT: LT. A.C. PERRY BOMBARDIER: CAPT. M.F. SUMMERFELT SHOT : CLFAR YRAIL AND R.S. BASED ON BT-2000-8-1 AIR : SMOOTH GRIND CLINE AIR SPEED DEVIATIONS FROM TARGET SPEED CR HOR. BOME ALT JOR'NO | CAL TRUE RANGE DEFLECTION JE. LAIR GR'NO GR'ND GR'NO RANCE NO. 033 005 1810 OVER SHORT RIGHT LEFT | 038.1 038.1 038.1 <u>2</u>28.1 FT. PVAR WAR PYHR PYHR PURE FT. FT. PFT. 5.40 33308.03161 120 178.5 170.0 114.6 +73.0 5418 609 105 155.8 159.3 105.6 -126.7 5798 240 2 3.50 23125124972 -171 5 5 4251 120 34.3 ·22.J 1.017 1.016

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## RESULTS OF RANGE BOMBING NO. 158 MAY 27, 19-1 ICCO LB. A.P. BOMB TI AIRPLANE B-18A

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### Appendix C

Individual Standard Elements and Ballistic Coefficients from Reduction of Field Data

Appendix C

			•		• •	,	<del>-</del>			
			Y	υ	х	T	λ	CX	$c_{\mathtt{T}}$	c <sub>\lambda</sub>
(	rogram Group Serial	Date of Release Run No.	Standard Altitude	Standard True Air Speed	Standard Range	Standard Time of Flight	Standard Trail			
1	Number		ft.	mi./hr.	ft.	sec.	ft.			
	-11	4/28/41-1	25000	200	11185	40.92 WE 41.25	818 915	4.27	4.26 3.39	4.26 3.77
	-12 -15 -14	2 4/29/4 <b>1-</b> 1 2	10000	160	11372 5753 5775	41.32	748	8.53 5.46 7.00	3.24	4.68
	-13 -16 -17	3 5/3/41 <b></b> 1	25000	200	5776 11280	WE 25.12 25.14 39.72	119 124 372	7.14 5.74	9.94 8.61 24.25	8.00 7.70 9.95
70	-18	2			11289 11367	WE 41.85 41.50	98 <b>7</b> 808	5.92 8.32	2.44 2.91	3.65 4.41
	-19	2			11195	40.89 WE 40.93	799 812	4.38	4.36 4.22	4.46
	-20 -21	5/26/41-1 2	10000	160	5691 5743	25.20 25.24 WE 25.05	223 179 135	3.34 4.96	6.71 5.90 16.30	4.27 5.06 7.08
	-22 -23	3 5/27/41 <b>-</b> 1	2000	160	5705 2510 <sup>1</sup>	25.34 10.80 <sup>1</sup> WE 10.89 <sup>1</sup>	242	3.68	4.30	3.94
	<del>-</del> 24	6/3/411	2000	160	2623	11.18 WE 11.22	1 10	-19.60	8.89 4.10	135.39 17.60

<sup>1</sup> Not included in group mean for reasons given on page 8 of text.

### Appendix C (Cont'd)

			Y	Ū	Х	Т	λ	$c_{X}$	$\mathtt{C}_{\mathbf{T}}$	C <sub>\lambda</sub>
	- ,	Date of Release Run No.	Standard Altitude ft.	Standard True Air Speed mi./hr.	Standard Range ft.	Standard Time of Flight sec.	Standard Trail ft.			
}	-25	6/3/411	2000	160	2623	11.18 WE 11.34	1 38	-21.14	10.44	220.02 4.61
	26 27	6/6/411	2000	160	2613 2572	11.16	46	24.33 2.42	91.02	3.79

#### Appendix D

Mean Standard Elements of Altitude Groups and Relations Between the Ballistic Coefficients and the Altitude of Release

Appendix D Table 1 Range

Y	ប	V	N	P.	Х	$\mathbf{r}_{\mathbf{X}}$	c <sub>X</sub>	$^{\mathrm{r}}c_{X}$	c <sub>X</sub> y	X-X <sub>f</sub>	
Standard Altitude		Calibrated Indicated Air Speed Corre- sponding to Standard True Air Speed	Number of Bombs	οĒ	Standard	Probable Error of Mean Standard Range	Correspond-	Probable Error of Ballistic Coefficient Correspond- ing to Mean Standard Range	Value of Ballistic Coefficient from C:Y Relation	Mean Standard Range Minus Range Corre- sponding to C y	
ft.	mi./hr.	mi./hr.			ft.	ft.				ft.	
35000									5.43		
30000		•			·		,		5.45		
25000	200	134.8	. 6	1.00	11281	22.2	5.76	0.460	5.48	. 14	
20000		,		ı		·			5.52		
15000		,	,					•	5.58		
10000	160	136.6	6	1.33	5740	9.8	4.85	0.428	5.69	-16	
5000									5.95		
2000	160	155.0	4	0.67	2608	8.2	11.32	9.455	6.53	7	

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Appendix D Table 2 Time of Flight

Y	ט	٧	N	P	Т	$\mathtt{r}_{\mathtt{T}}$	$\mathtt{c}_{\mathtt{T}}$	r <sub>C</sub> T	<sup>C</sup> Ty	T-T <sub>f</sub>
Standard Altitude	Standard True Air Speed	Calibrated Indicated Air Speed Corre- sponding to Standard True Air Speed	Number of Bombs	of	Standard	Probable Error of Mean Standard Time of Flight	Ballistic Coefficient Correspond- ing to Mean Standard Time of Flight	Probable Error of Ballistic Coefficient Correspond- ing to Mean Standard Time of Flight	Value of Ballistic Coefficient from C:Y Relation	Mean Standard Time of Flight Minus Time of Flight Corre- sponding to CT y
ft.	mi./hr.	mi./hr.			sec.	sec.				sec.
35000	<del></del>	;							4.28	
3000 <b>0</b> .								,	4.28	
25000	200	134.8	6	1.00	41.05	0.150	3.87	0.409	4.28	0.12
20000				٠,					4.28	
15000							: '		4.28	
10000	160	136.6	5	1.33	<b>23518</b> 8	0.028	7.25	0.861 (-	4.28	-0.17
5000							٠.		4.28	• •
2000	160	155.0	3	0.67	11.22	0.022	4.45	1.532	4.28	0.04

Appendix D Table 3 Trail

Trall										
Y	ט	ν	N	₽	λ	${ m r}_{\lambda}$	c <sub>λ</sub>	r <sub>C</sub> $\lambda$	С <sub>У</sub>	$\lambda - \lambda_{\mathbf{f}}$
Standard Altitude	Standard True Air Speed	Indicated Air Speed Corre- sponding to Standard True Air	of	of	Mean Standard Trail	Probable Error of Mean Standard Trail	Coefficient Correspond-	Probable Error of Ballistic	Value of Ballistic Coefficient	Mean Standard Trail Minus Trail Corre- sponding to C y
ft.	mi./hr.	Speed mi./hr			ft.	ft.				ft.
35000 ·									4.41	
30000		6			ş			•	4.48	
25000	200	134.8	6	1.00	<b>7</b> 75	49.0	4.52	0.308	4.57	7
20000					·			,	4.69	
15000					,			•	4.89	
10000	160	136.6	5	1.33	172	15.9	5.56	0.517	5.26	-10
5000									6.34	
2000	160	155.0	. 3	0.67	21	7.7	8.31	2.974	10.73	5

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